TEMPORAL EVOLUTION STEPS OF JOVIAN NARROW–BAND EMISSIONS

M. Y. Boudjada*, P. H. M. Galopeau†, H. O. Rucker*, and A. Lecacheux‡

Abstract

Very few works are devoted to the analysis of the Jovian narrow–band emissions because these emissions are relatively infrequent phenomena. From the Riihimaa catalogue [1992] we select narrow–band events observed in Oulu (Finland) with an acousto–optic spectrograph (AOS) with a time resolution of about 7 ms. Riihimaa reported in his catalogue a summary of the main dynamic spectra based on real–time high resolution observations of Jovian narrow–band and Jovian fine structures, i.e. Jovian millisecond radio bursts. The analysis of the temporal evolution of the Jovian narrow–band leads to a new interpretation of the individual fine structures as described by Riihimaa [1992]. Each structure could be decomposed in one, two or three components depending on the way the narrow–band is perturbated. We discuss and compare our findings to three models: adiabatic model [Ellis, 1965], feedback model [Calvert, 1982] and filamentary model [Louarn, 1997].

1 Introduction

1.1 Jovian narrow–band (NB)

The first description of Jovian narrow–band (NB) was reported by Riihimaa [1968a] who found that this emission often exhibits a slow and stable drift in frequency. Later on, a receiver with better high resolutions (few dozens of milliseconds) enabled the findings that such emission looks like trains of millisecond bursts (S–bursts) with a relatively small total bandwidth [Krausche et al., 1976; Flagg et al., 1976; Riihimaa, 1977; Riihimaa, 1985]. Also Leblanc and Rubio [1982] have reported another type of narrow–band, the so–called "splitting" which appears on wideband dynamic spectra as bands of emission at the higher frequency limit of the emission and associated closer to the Io–B region. Boudjada et al. [1995a] described similar "splitting" but in the Io–C region at a frequency lower than 22 MHz. It is important to note that the "splitting" in Io–B and Io–C regions is observed with right–hand and left–hand circular polarizations, respectively.

*Space Research Institute, Austrian Academy of Sciences, Schmiedlstrasse 6, A–8042 Graz, Austria
†Centre d'Etude des Environnements Terrestre et Planétaires, F–78140 Velizy, France
‡ARPEGES, Observatoire de Paris–Meudon, F–92190 Meudon, France

1.2 Riihimaa classification

The Riihimaa classification shows sketches of Jovian millisecond radio bursts as they appear on dynamic spectra and to each type of structure an alphabetic letter is associated allowing to recognize one S–burst from another (see Figure 1). The classification begins with a simple structure like *type a* which appears as straight line in the dynamic spectrum, to more complex structures with changing sign of its slope (with positive and negative drift–rates) as in the case of *type f*.

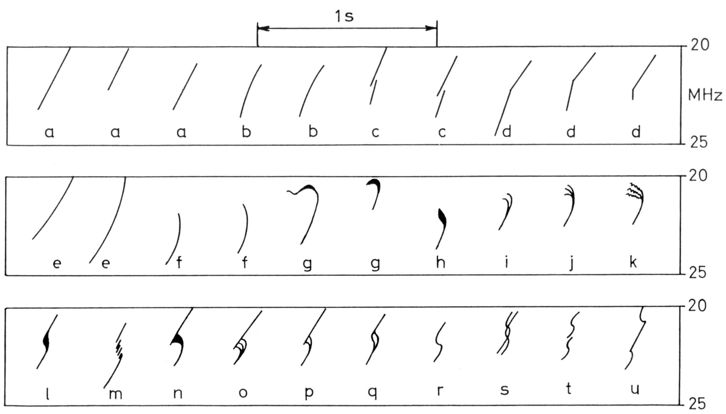

Figure 1: Riihimaa classification.

More precise analysis of the Riihimaa structures reveals that each individual S–burst is the composition of three parts where sometimes all are observed and sometimes only one or two of them. The first one, *type 1*, is the central part of the structure where we note an infinite value of the drift rate (DR) when it changes sign, e.g. upper part of *type g* and *type h*, or central part of *type l* and *type r*. The second part, *type 2*, is the upper part of the individual S–burst which appears as a straight segment (e.g. *type l, m, n, o, p, q*) or as a curvature with increasing slope (e.g. *type b* and *r*). The third part, *type 3* could be (a) related to *type 1* (e.g. *type g, h, i, j, k, l, m, n, o, p, q, r*), (b) connected to *type 2* (e.g. *type d*) or (c) alone (e.g. *type f*).

2 Narrow–band temporal evolution

2.1 Narrow–band events

Since the discovery of the Jovian millisecond radio bursts, three main catalogues [Ellis 1979; Flagg et al. 1991; Riihimaa 1992] were published. Riihimaa [1991] was the first to report a very interesting classification of S–bursts mainly based on the observations described in his catalogue (see Figure 1).

The observations were made at Oulu in Finland at a latitude of about 65°N. Using two log–periodic antennas connected to different types of equipment (a swept–frequency receiver,

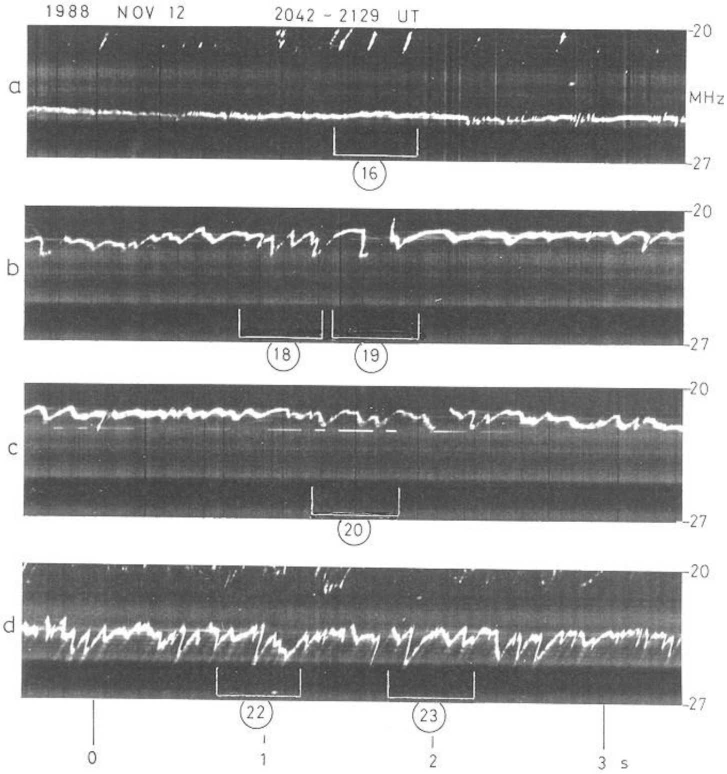

Figure 2: Temporal evolution of the Jovian narrow–band and the occurrence of type V structure

a multichannel receiver and an acousto–optic spectrograph). The main characteristics of the Riihimaa catalogue are: (a) observations from midnight to the early morning hours local time when the ionospheric electron density was very low, (b) a receiver band frequency from a few Megahertz to 12 MHz, (c) and sometimes measurements of the sense of polarization.

Riihimaa reported in his catalogue a summary of the main dynamic spectra based on real–time high–resolution observations of Jovian millisecond radio bursts. The selected events displayed in Figures 2, 3 and 4 are very representative of a general behaviour of the NB. In Figure 2, four dynamic spectra are shown which have been observed on November 12, 1988 by the acousto–optic spectrograph (AOS). At first we note a quasi–continuous narrow–band emission followed by a second one where we note the appearance of *type V* structures. In this event, shown in Figure 3, the evolution of the narrow–band is associated to the evolution of *type V* where one component is still connected to the NB whereas the second one is disconnected. The dynamic spectrum shown in Figure 4 presents several individual S–bursts similar to those reported in the Riihimaa classification. The upper-part, the central part and the down-part are associated to *type 2*, *1*, and *3*, respectively.

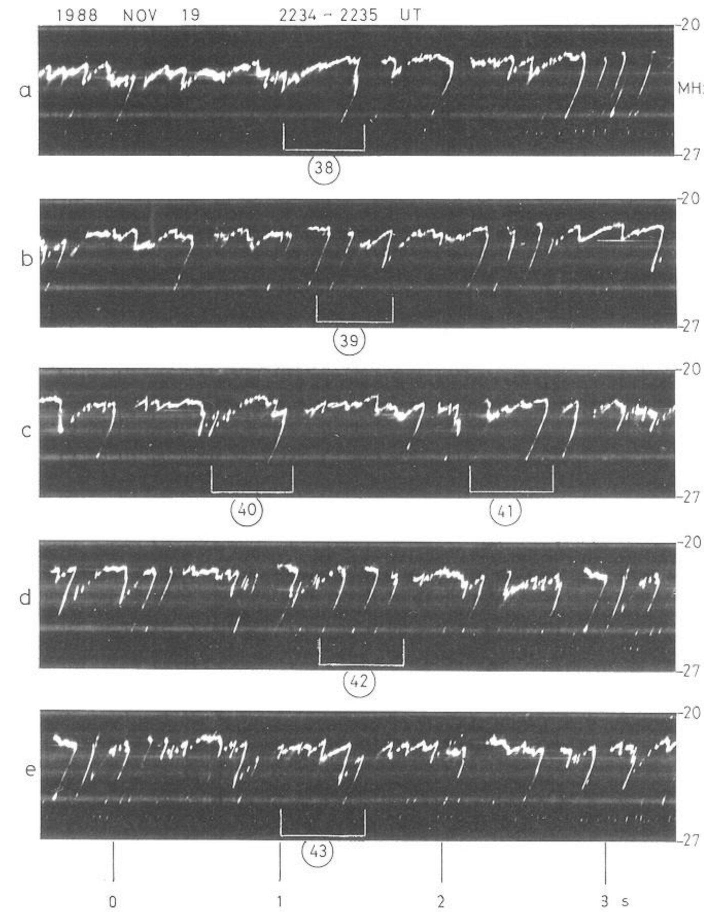

Figure 3: The evolution of the narrow–band shows that one component of type V is still connected to NB when the other is totally disconnected

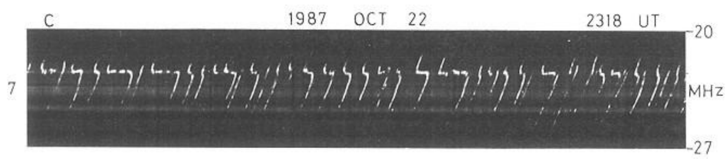

Figure 4: The narrow–band disappeared and only the Riihimaa structures are observed

2.2 Temporal evolution of the Jovian narrow–band

The selected four events are very representative of the general behaviour of the NB for which four steps can be detected in the temporal evolution. In the first step, the NB appears as a continuous band emission with an instantaneous frequency bandwidth of about 200 kHz, and sometimes as discontinued emissions with a variable gap duration of about 20 to 40 ms. In the second step, perturbations appears in the NB where the type V is the fundamental structure. In the same time the duration of the gaps increases up to more than 80 ms. In the third step, the number of *type V* increases, some of them remain connected to the NB while the others have only one component connected to the narrow–band; we note the absence of millisecond radio bursts in the first previous steps. In the last step the *type V* is totally disconnected from the NB and finally the Riihimaa structures appear. The *type 1* of the individual S–burst is the remainder of the narrow–band and the *type 2* and *3* are associated to the discontinuity of the NB.

3 Discussion on models

The analysis of temporal variations of the narrow–band has shown that the S–bursts seem to be sub–structures generated inside a more global structure, i.e. the narrow–band. This new approach is different from the previous ones which consider that the narrow–band and the individual structure (also so–called sub–structure or fine structure) are two different kinds of emissions. In the framework of our study we discuss in the following the classic model [Ellis, 1965] and two other models (the feedback model, Calvert [1982]; the filamentary source model, Louarn, [1997]) which seem to account for a number of observational characteristics of the narrow–band as reported in our analysis.

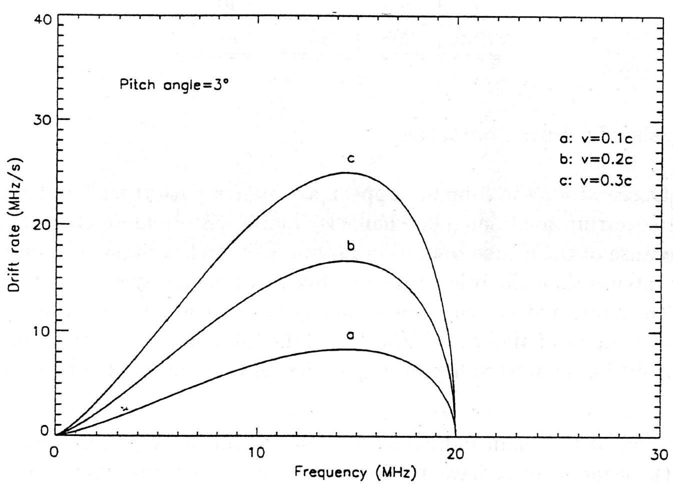

Figure 5: Classic model proposed to explain the S–burst negative drift–rates [Boudjada et al., 1996].

The Ellis model considers that the observed negative drift rates are due to the adiabatic motion of electrons along magnetic field lines in the Jovian magnetosphere. However, investigations of Boudjada et al. [1996] and Galopeau et al. [1999] show that the instantaneous drift rate of one individual S–burst cannot be fitted by fixing the initial pitch angle and the electron speed as in the case of this model (see Figure 5). The feedback model is comparable to an optical laser oscillator where the sub–structures are due to self–excited wave oscillations generated inside the source (see Figure 6). The frequency bandwidth of the AKR discrete components is about 20 kHz, at least 10 times smaller than the Jovian S–bursts. The drift rate is due to the changing product of the source width and refractive index. However, this model does not take into consideration the presence of the fundamental narrow–band. The filamentary model (see Figure 7) considers the spectral structures to be related to the spatio–temporal organization of the source versus the observer. This is in agreement with the S–burst occurrence which is modulated by the geometrical conditions. However, it seems that the NB features because of the short time scale gap and the individual S–burst duration, are intrinsic to the source contrary to the model prediction.

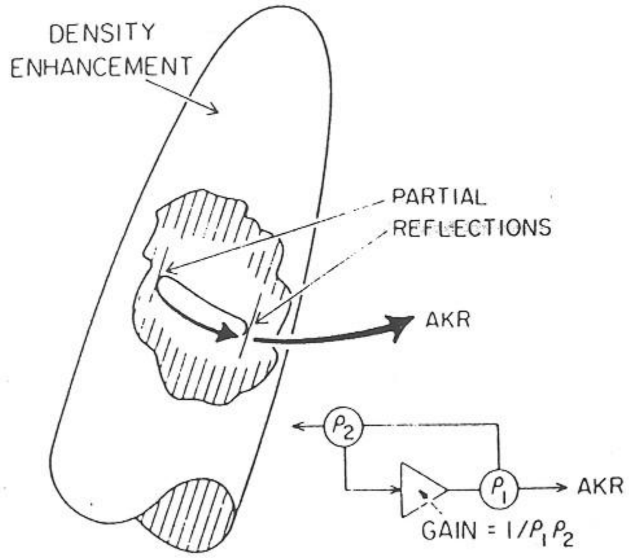

Figure 6: Feedback model proposed to explain fine structures observed in the Auroral kilometric radiation (AKR) [Calvert, 1982].

4 Conclusion

It is shown that the temporal evolution of the NB involves the presence of fine structures which seem to be the residue of the narrow–band. The short time scale of the gaps in the band account for a mechanism which seems to be intrinsic to the source. We discuss and compare our results to three models: (a) the Ellis model cannot explain the relation between the narrow–band and the inherent fine structures, and the two others (b) the feedback model and the (c) the filamentary model could be adapted to explain part of the observed feature but not the global observed phenomena.

All those models explain only part of the observed features and more investigation should emphasis on the relationship between the narrow–band and the fine sub–structures. Finally we hope to compare our investigation to the recent investigations reported during this meeting [Carr, 2001; Oya et al., 2001; Willes, 2001].

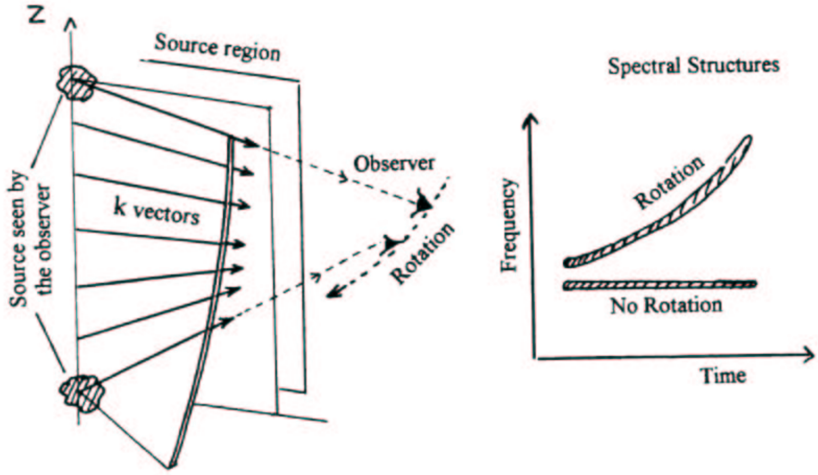

Figure 7: Filamentary model which take into consideration the spatio–temporal organization of the source [Louarn, 1997].

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